TECHNICAL MEMORANDUM CH2MHILL®

City of Alexandria Storm Sewer Capacity Analysis

Planning Level Cost Information

PREPARED FOR:	City of Alexandria Transportation and Engineering Services
COPY TO:	File
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Introduction

The City of Alexandria, Virginia, has experienced repeated and increasingly frequent flooding events attributable to old infrastructure, inconsistent design criteria, and perhaps climate change. The purpose of the stormwater capacity analysis project is to provide a program for analyzing storm sewer capacity issues, identifying problem areas, developing and prioritizing solutions, and providing support for public outreach and education. The project is being implemented in phases by watershed. The watersheds include Hooffs Run, Four Mile Run, Holmes Run, Cameron Run, Taylor Run, Strawberry Run, Potomac River, and Backlick Run.

This technical memorandum provides details on the basis of cost estimates developed for each solution and the watershed wide alternatives. The information includes panning level unit cost for conveyance, storage and green infrastructure solutions.

These cost estimates are considered a Class 4 - Planning Level estimate as defined by the American Association of Cost Engineering (AACE), International Recommended Practice No. 18R-97, and as designated in ASTM E 2516-06. It is considered accurate to +50% to -30% based up to a 15% complete project definition.

Definitions

The following cost terminologies are used within this technical memorandum:

- Construction cost: Installed cost, including materials, labor, and site adjustment factors such as overcoming utility conflicts, dewatering, and pavement restoration.
- ENRCCI Cost Adjustment Factor: Cost adjustment factor of 0.9 to adjust cost to October 2013 dollars for the DC-Baltimore metro area
- Service and Contingency Factor (SCF): A factor of 1.4 is applied for this project to account for engineering and design expenses (20%) and for contingency allowance (20%).
- Capital cost: Construction cost multiplied by a Service and Contingency Factor (SCF) to cover engineering and design and contingency allowance.
- Operating cost: Operation and maintenance were not considered for this project.

Gravity Sewer Relief Costs

Conveyance projects were costed on a per linear foot basis, based on pipe size and depth. The construction cost rates ($/ft) for gravity sewer replacement are listed in Table 1. Cost rates are shown for different road types. The Gravity sewer cost rates include complete installation of sewer pipes, inlets/manholes, and other ancillary structures as well as surface restoration. The costs were established through literature review and updated based on an assessment of bid tabulation data from Kansas City metro area between 2008 and 2012, and a comparison to Fairfax County, VA unit cost schedule, March 2013. All costs were adjusted to Washington DC, 2013 dollars using Engineering News-Record Construction Cost Index (ENRCCI) adjustment factors.

Factors are applied to the construction cost of gravity sewer pipe replacement to reflect the cost associated with crossing under streams and railroads as listed in Table 2.

Costs of routine O&M, inspection and cleaning at periodic intervals during the life of the gravity sewer were assumed to part of City-wide facilities maintenance plan and should take place even though those costs are not specifically included here.

TABLE 1
Open Cut Gravity Sewer Construction Costs

		Sewer Construction Cost ($/LF) (1)					
		Trench depth up to 10 feet		Trench depth 10 to 15 feet		Trench depth 15 to 20 feet	
Pipe Diameter (in)	Material	Residential	Arterial	Residential	Arterial	Residential	Arterial
8	PVC	$90	$104	$113	$130	$140	$162
10	PVC	$113	$131	$140	$163	$176	$204
12	PVC	$122	$140	$152	$175	$190	$218
15	PVC	$131	$153	$163	$192	$204	$239
18	PVC	$140	$162	$175	$203	$218	$253
21	PVC	$162	$189	$203	$237	$253	$295
24	PVC	$185	$212	$230	$265	$288	$330
30	RCP	$257	$297	$320	$372	$401	$464
36	RCP	$306	$356	$383	$445	$478	$555
42	RCP	$360	$414	$450	$518	$563	$647
48	RCP	$410	$473	$512	$590	$640	$738
54	RCP	$459	$531	$574	$664	$717	$830
60	RCP	$509	$585	$635	$732	$795	$914
72	RCP	$815	$936	$1,018	$1,170	$1,273	$1,463

(1) Listed construction costs have been adjusted to October 2013 dollars using ENRCCI for the DC-Baltimore Metro area.

TABLE 2
Gravity Pipe Construction Cost Factors

Type of Crossing	Cost Factor
Stream	3
Railroad	7

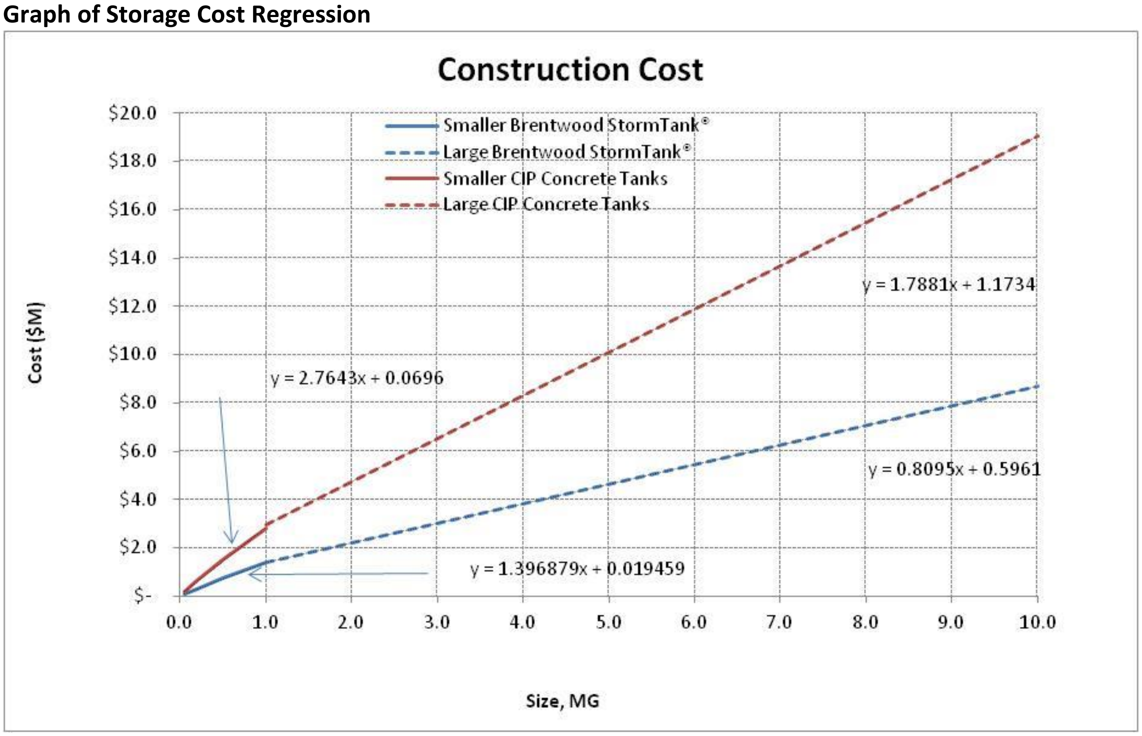
Storage Facility Cost Information

Cost estimates for the storage facilities were developed for two technologies: A traditional underground cast-in-place concrete tank and an alternative stackable modular unit installed underground and wrapped with an impermeable or permeable liner.

The CIP Concrete storage facility construction cost was developed as a customized cost estimate based on CH2M HILL's Program Alternative Cost Calculator (PACC) Tool. The costs are construction costs only and do not include administration costs, engineering costs, contingencies, and other soft costs. The costs for smaller storage units with volumes less than 1 million gallon were found to be high for the CIP concrete tank. Hence, a separate takeoff cost estimate was developed for smaller storage volume; less than 1 million gallons.

A separate cost estimate was developed for the stackable modular units. There is an increasing use of these technologies in the industry and the cost of installation is getting increasingly competitive compared to traditional storage methods. Construction costs were developed based on one such stackable modular unit, StormTank® modules by Brentwood Industries. The cost for the Brentwood StormTank® modules came out significantly less than that for CIP concrete tanks. For the purpose of the evaluation of watershed wide alternative solutions, the StormTank® modules was used as the most cost effective alternative, however site specific conditions will determine which technology will be most appropriate in a given location. For example a site with high water table may make the use of CIP concrete tanks preferable over the StormTank® modules. The estimated construction costs for the CIP concrete tanks and the Brentwood StormTank® are provided in Figure 1.

FIGURE 1
Graph of Storage Cost Regression



The following assumptions were made for storage tank selection and sizing:

1. Offline enclosed underground storage will be active only during wet weather events.
2. Options for odor control were not considered.
3. Costs for storage facilities with intermediate storage volumes were interpolated based on linear regression shown in Figure 1.

Green Infrastructure (GI) Cost Information

A variety of sources and professional judgment were used to develop the GI costs. Where technologies were directly comparable, costs were updated based on Fairfax County, VA unit cost schedule, March 2013. The unit costs used to develop GI implementation cost are included in Table 4. Costs reflecting stand-alone projects (e.g., installing a green roof on top of an existing building) were used for costing alternatives solutions. Incremental costs of adding GI to an existing project can provide significant savings and are provided for reference, but not used directly in cost estimates for this project.

In the CASSCA Project GI is being proposed as a series of GI programs applicable to specific land uses (e.g. green parking is applicable to parking lots). Each GI program may consist of multiple GI technologies which drive the cost of implementing that program. Table 5 lists and the relative amounts of area designated for the GI technologies assumed to be part of each GI program and the resultant unit cost for each GI program.

TABLE 4
Unit Construction Costs of Green Infrastructure Technologies

Green Technology	Stand Alone Cost Proposed for GI Plan ($/GI acre)	Loading Ratio (Ratio of Area Managed to Area of GI)	Stand-Alone Cost Proposed for GI Plan ($/acre managed)	Incremental GI Cost Compared to Stand-Alone
Native Landscaping/Soil Amend.	$ 5,000	1	$ 5,000	50%
Rain Barrels[1] and Native Landscaping/Soil Amend.	$ -	N/A	$ 15,000	90%
Cisterns[2]	N/A	N/A	$ 34,000	90%
Blue Street/Inlet control devices	N/A	N/A	$ 22,500	N/A
Rain Gardens	$ 436,000	12	$ 36,000	70%
Stormwater Trees[3]	$ 34,700	0.5	$ 69,000	50%
Bioswale/Bioretention	$ 1,045,000	12	$ 87,000	70%
Porous Pavement/ Infiltration Trench	$ 436,000	4	$ 109,000	70%
Green Roof[4]	$ 501,000	1	$ 501,000	43%

[1] Each rain barrel is assumed to manage 350 ft^2 of rooftop; therefore, 124.5 barrels are required for 1 acre of roof.
[2] Each 1000-gallon cistern is assumed to manage 6,500 ft^2 of impervious area; therefore, 6.7 barrels are required for 1 acre.
[3] Trees are assumed to have an average 10-foot canopy radius (314 ft^2), with 50 percent assumed to be overhanging impervious area.
[4] Incremental cost of green roofs set to 43 percent to match the District's $5/ ft^2 ($217,800/acre) green roof incentive program.

TABLE 5
Green Infrastructure Technology Elements and Unit Construction Cost of Each Green Program

Green Technology	% Area of Program Assigned to Each GI Technology						
	Blue Streets	**Green Alley**	**Green Buildings**	**Green Parking**	**Green Roofs**	**Green Schools**	**Green Schools**
Native Landscaping/Soil Amend.	-	-		-	-	-	-
Rain Barrels[1] and Native Landscaping/Soil Amend.	-	-	30%	-	-	-	-
Cisterns	-	-	10%	-	-	-	-
Blue Street/Inlet control devices	100%					-	-
Rain Gardens	-	-	30%	-	-	-	-
Stormwater Trees	-	-		-	-	-	30%
Bioswale/Bioretention	-	-	30%	50%	-	65%	30%
Porous Pavement/ Infiltration Trench	-	100%		50%	-	30%	40%
Green Roof	-	-	-	-	100%	5%	-
Unit Cost ($/acre managed)	**$22,500**	**$109,000**	**$44,800**	**$98,000**	**$501,000**	**$114,300**	**$90,400**

Three levels of green infrastructure implementation were evaluated for this project:

- High Implementation – Manage 50% of total impervious area in the shed
- Medium Implementation – Manage 30% of total impervious area in the shed
- Low Implementation – Manage 10% of total impervious area in the shed

The unit cost of implementing GI at the various implementation levels is driven by the availability of GI opportunity areas. As the area available to achieve a GI implementation level become scarce, the cost to achieve that level on GI implementation also increases. It was assumed that GI implementation would focus, in succession, from the most to the least cost effective programs and technologies. That is, for each level of GI implementation the most cost effective program and technologies would be implemented first until the available opportunities for those programs are exhausted. If the level of implementation is not achieved with the most cost effective program, the next most cost effective program is considered in that order until the desired level of GI implementation is achieved. Therefore Low Implementation would be more cost effective (lower cost per acre managed). The unit cost for each implementation level was computed separately for each watershed based on the cost information presented above and the distribution of areas available for GI implementation.

Green Opportunities

Opportunities for blue streets, green streets and alleys, green buildings, green parking, green roofs, and green schools were identified by completing a desktop analysis using the City's 2011 basemap data, including:

- Roads (Road_y and Road_lc)
- Buildings (Blds_y)
- Parking lots (Parking_y)
- Zoning (Zoning_y)
- Parcels (Parcels_y)

The approach to identifying potential opportunities for each program is provided below. All opportunities were combined into a single shapefile of polygons with an attribute for area calculated in acres.

Blue Streets

Local or Residential roads with an average slope less than or equal to 1% and a maximum slope less than or equal to 3%. Road slope was estimated using ArcGIS 3D Analyst tools and the Road_lc feature and City of Alexandria DEM as inputs.

Green Streets and Alleys

Green streets and alleys were identified using the Road_lc and Road_y features to identify roads classed as Arterial, Primary Collector, Residential Collector, Local, and Alley with an average slope less than or equal to 5%. Roadways that fall within school parcels were removed from this layer because they are included in the Green Schools program. Road slope was estimated using ArcGIS 3D analyst tools and the Road_lc feature and City of Alexandria DEM as inputs.

Green Buildings

Green buildings opportunities include buildings where disconnection may be possible. Based on a windshield survey of Taylor Run, approximately 50% of residential buildings, not including single family detached homes, may have opportunities for downspout disconnection. To identify these opportunities, buildings with a BUSE of '1-Residential' were selected from the Blds_y features to identify all residential buildings. This selection was narrowed to apartment buildings and larger residential developments, removing detached houses (BTYPE = 'Detached house'), buildings with less than 5 units (BUNITS < 5), as well as removing nursing homes, hotels, and detention centers. Residential buildings on school properties were also removed because those are accounted for in the Green Schools program. Buildings with a footprint greater than 20,000 square feet were also removed because these buildings are likely too large for a disconnection program.

The footprint of the final selection was reduced by approximately 50% (based on the result of the Taylor Run windshield survey) to approximate the total area of impervious surfaces that could potentially be managed through a disconnection program.

Green Parking

Green parking opportunities were identified as parking lots in the Parking_y feature class with a parking area over 3,000 square feet. Parking lots on school parcels were removed from this selection because they are accounted for in the Green Schools program.

Green Roofs

Green roof opportunities were identified by selecting buildings in the Blds_y feature class with a footprint over 20,000 ft^2 that have a building use (BUSE) of Commercial, Industrial, Institution, Transportation, and Multiple or Mixed use. Also included were buildings over 20,0000 ft^2 that were within a Commercial, Industrial, Coordinated Development District, or Mixed Use zone based on the Zoning_y feature class, unless those buildings were garage/sheds. Buildings on school parcels were removed from this selection because they are accounted for in the Green Schools program.

Green Schools

School parcels were identified by selecting all parcels with a land description (LANDDESC) of 'ED. PUBLIC SCHOOLS', 'PRIVATE ED ENSTS.', or 'ST. ED. INSTITUTIONS' or with an owner name or address that indicated it was school property. School buildings with potential for green roofs were identified by selecting all buildings on school parcels or buildings in the Blds_y features with the word 'school' in the building name (BNAME) or building campus (BCAMPUS) fields where the footprint is over 3,000 ft^2. All remaining impervious surfaces on the school parcels (roads, sidewalks, small buildings, recreation facilities, etc.) were identified as opportunities for green schools.